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EMERGENCY DISINFECTION OF OPERATING ROOM AND PATIENT WARD WITH BETA-PROPIOLACTONE

by MANUEL S. BARBEITO

PREOPERATIVE examination of the leg stump of a male patient in a five-bed ward at the Frederick (Md.) Memorial Hospital disclosed possible infection with one or several of the organisms that produce gas gangrene. During examination of the wound by the attending physician, flowing pus contaminated the bed clothes and the asphalt-tiled floor. Secondary contamination of surfaces probably was caused by the liberated bacterial aerosol. Subsequently, the wound was dressed and the patient prepared for surgery. Other patients in the ward at the time the wound was examined were transferred to other locations throughout the hospital.

Once the tentative diagnosis was made that the patient had gas gangrene, the ward was declared an isolation area. The pillows in the ward were placed in plastic bags, which were then sealed, removed from the ward, transported to an autoclave, and sterilized with ethylene oxide.¹ After placing the pillows in the autoclave equipped

The author reports how beta-propiolactone vapor was used to disinfect a community hospital ward and operating room following their potential contamination with clostridial organisms. He describes the methods employed to accomplish the disinfection and the tests used to show its efficiency.

for use with ethylene oxide,² the plastic bags were punctured and ethylene oxide was added to the autoclave in the prescribed manner. The pillows remained in the autoclave for 18 hours,³ and were then aerated for a minimum of 48 hours before being used. Because the mattresses were protected with sheets and an impermeable protective covering, it was decided that the sheets would be removed and handled in the manner prescribed for disposal of contaminated linens. The mattresses with a plasticized covering were scrubbed with a detergent-disinfectant solution, removed from the ward, and placed in the sunlight for eight hours.

After reamputation and a period spent in the postoperative recovery room, the male patient was trans-

ferred to another room within the hospital.

Upon completion of surgery, the operating room was isolated and the equipment remained within the room. The operating room staff entered the room with protective operating room clothing and wiped all surfaces and equipment with toweling soaked in a solution of detergent-disinfectant.

At a meeting of the infectious disease committee of the Frederick Memorial Hospital, a decision was reached to ask the assistance of the Industrial Health and Safety Division, U.S. Army Biological Center (Provisional), Fort Detrick, in regard to a practical and safe method by which to disinfect the operating room and ward. After examining the facilities, Fort Detrick personnel decided that the most feasible method to accomplish disinfection was through the use of beta-propiolactone (BPL) as a vapor.^{4,5} In addition, they concluded that the disinfection would be done after all scheduled surgery for the day was completed to eliminate the possibility of hav-

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*Disinfect as used in this report means that the chemical agent, beta-propiolactone, acted as a bactericide and sporicide.

ing BPL vapors enter the other operating rooms during an operation, either through leakage within the building structure or through the exhaust supply ventilation system. Another factor considered before disinfection with BPL was the wind direction and general atmospheric conditions. The weather on the evening when the operating room was disinfected was clear and warm with a southerly wind that carried the vapors away from the air supply duct. The afternoon when the ward was disinfected also was warm and clear with a westerly wind. The ward was disinfected in the afternoon because the possible problems associated with entry of BPL into other areas were far less than if BPL were to enter the operating rooms.

Because the normal bacterial flora of the facilities to be disinfected was not known, it was decided that spores of *Bacillus subtilis* var. *niger* would be used as a bacterial tracer to determine the efficacy of the disinfection. By personal experience and extrapolation it was concluded that if *B. subtilis* and *Bacillus anthracis* spores are killed with BPL,⁶ both the vegetative and spore states of clostridia organisms would be killed.⁷

DESCRIPTION OF FACILITIES

The operating suite is located on the top (third) floor of the hospital at the far end of one wing. The walls and area around the window of the operating room used for surgery on the gas gangrene wound case are ceramic-tiled up to a height of 7 ft. 1½ in. The remainder of the walls and ceiling are plastered and covered with an oil-base paint. The floor covering is resilient conductive rubber. Figure 1, page 102, shows the layout of the operating room. The volume of the operating room is approximately 3738 cu. ft.

Equipment in the operating room during surgery and disinfection included: (1) face masks for use with anesthetizing gases; (2) anesthesia machine with associated gas cylinders and hoses; (3) stainless steel Mayo and instrument stands, stools, and kick buckets; (4) sealed jars of intravenous fluids; (5) wooden arm boards

with a rubber-covered sponge padding; (6) canvas restraining straps; (7) standard operating room lights, and (8) a suction machine used for aspirations.

The five-bed male ward is located approximately midway along the main corridor on the second floor. Figure 2, page 102, shows the layout of this ward, giving details about ventilating equipment and relationship to other hospital areas.

The walls and ceiling of the ward are plastered and covered with an oil-base paint, and the floor is covered with asphalt tile. The volume of the ward is approximately 3250 cu. feet.

Equipment within the ward during disinfection with BPL was as follows: (1) five metal bed frames with springs, (2) five metal bed stands with their normal contents, (3) two wooden chairs, (4) five metal footstools with rubber treads, and (5) three plastic waste buckets.

An analysis of the air entrances and exits, including location of windows and doors, exhaust fans and ducts, and air conditioning systems in the operating room and patient ward preceded the disinfection process. The relation of the potentially contaminated areas to other hospital areas was also considered.

OR DISINFECTION PROCEDURE

The operating room was prepared for disinfection by steps designed to make conditions of temperature and humidity favorable for the bactericidal action of the BPL vapor and to seal off the outlets in the ventilating and air conditioning systems in order to confine the vapor to the operating room. This was accomplished by:

1. Elevating the ambient room temperature to 75° F.

2. Raising the relative humidity to 75 per cent by injecting steam into the air supply system duct in the air conditioning system.

3. Taping the peripheral seams of the doors with pressure sensitive tape.

4. Turning off the air supply fan.

5. Sealing shut the door of a surgical instrument supply cabinet along one wall with pressure-sensitive tape.

6. Covering both the inlet supply

duct on the outside stairwell wall and the exhaust duct within the room with polyethylene film. This film was attached to the walls around the exhaust duct louver with pressure-sensitive tape. The film covering the exhaust duct louver within the operating room was equipped with a twine tear strip, and a heavy piece of twine extended to the adjoining hallway so that the polyethylene film cover could be removed from outside the operating room without the need for entering the BPL-laden room after the BPL contact time was complete. A piece of absorbent paper was placed beneath the generator to prevent possible damage to the floor during dissemination of the BPL vapor.

Before disseminating the BPL, 12 clearly delimited sites throughout the operating room were seeded with spores of *Bacillus subtilis* var. *niger* (count: 1×10^4 spores per ml.) by dipping a cotton swab into the liquid culture and transferring the spores onto the selected surfaces. Areas contaminated with the spores were wall, windowsill, and floor surfaces; scrub sink and soap dish; door handle; operating table; stands; and anesthetizing machine. The purpose of seeding the areas with spores was to determine the efficacy of the disinfection procedures.

Nine hundred milliliters of BPL were disseminated (amount calculated at a rate of one gal. for each 12,000 to 16,000 cu. ft. of space)⁷ with a generator.⁸ (See Fig. 1 for generator location.) Following dissemination of the BPL vapor and a two-hour contact period, the polyethylene films were removed, first from the exhaust louver by means of the twine run under the door into the corridor, and then from the supply louver. Then the exhaust fan was turned on. Air was exhausted for 30 minutes under this arrangement, which kept the operating room under a slight negative pressure and allowed fresh air to enter the room through the supply system. The supply fan was started two and one half hours after termination of BPL dissemination. With both the supply and exhaust fans on, the operating room was under a slight positive pressure, but because of

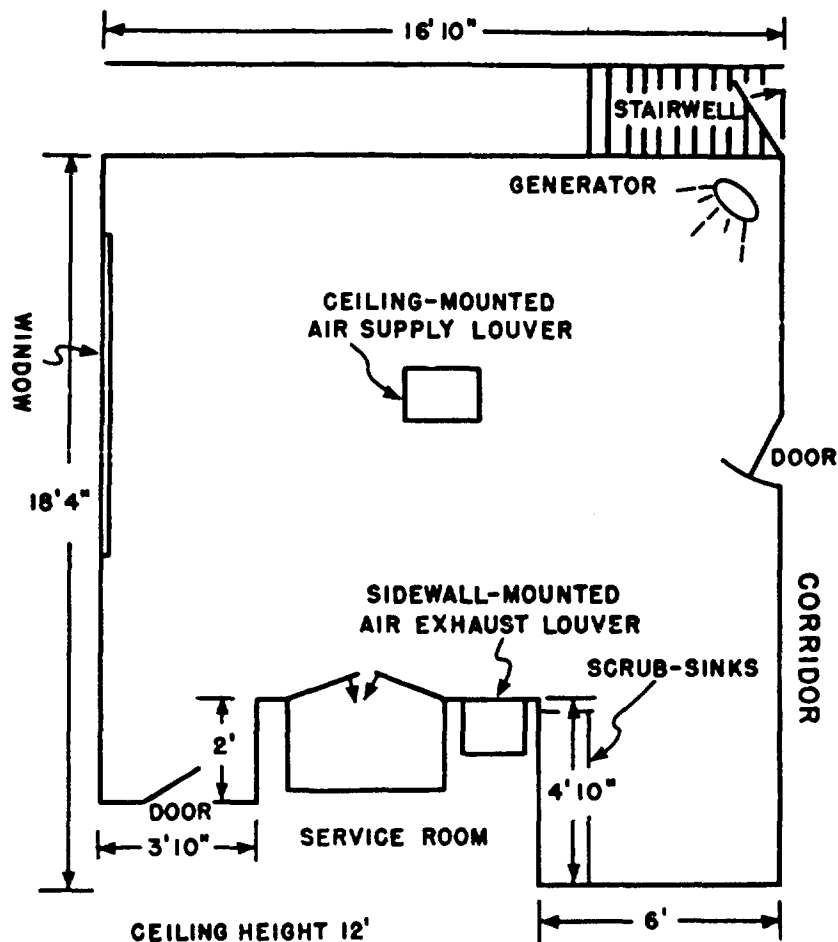
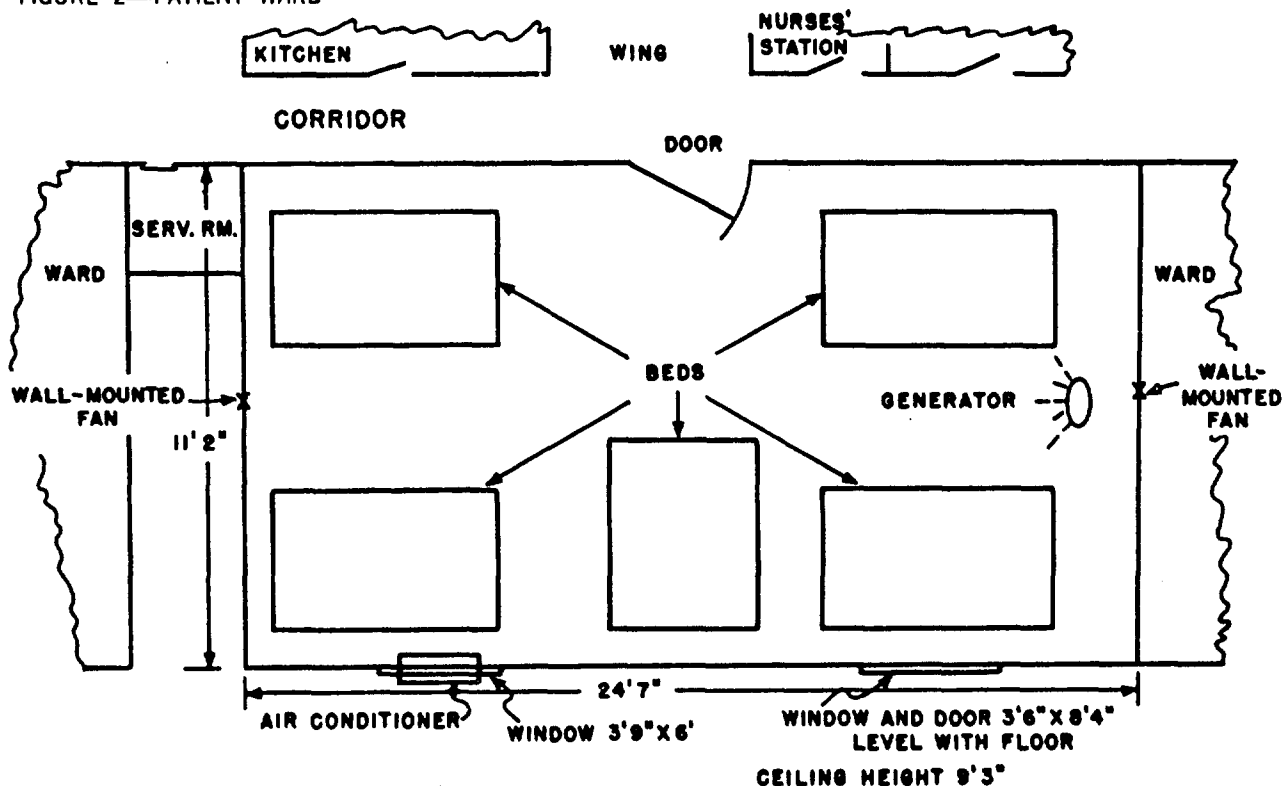


FIGURE 1—OPERATING ROOM

FIGURE 2—PATIENT WARD



the two-in.-wide pressure-sensitive tape sealing all cracks around the doors, the vapors of BPL did not enter the adjoining hallway or service room. After two and one half hours of aeration, a portion of the tape was removed from one door to permit sampling of the air for the detection of residual BPL vapors. Approximately 100 cc. of air from within the operating room was drawn through a chemical agent detection tube^{7,9} that will respond to BPL concentrations lower than 0.01 mg. per liter. The test is based on the appearance within the tube of a blue color caused by the reaction of BPL with the gamma (p-nitrobenzyl) pyridine absorbed on silica gel. The sensory systems of man himself will detect 0.05 mg. of BPL per liter of air.⁷

The 12 previously seeded areas were tested for the recovery of *B. subtilis* by two methods: surface plating and broth inoculation. In the surface plating technique, the 12 areas were sampled with sterile cotton swabs moistened with physiological saline. The cotton swabs were streaked on corn steep agar (see Appendix) in plastic petri

dishes and incubated at 37° C. for 48 hours. In the broth inoculation technique, a duplicate set of samples was taken of the seeded areas with sterile cotton swabs moistened with distilled water, aseptically transferred to thioglycolate broth tubes, and incubated at 37° C. for 24 hours. Controls were used in conjunction with the test samples and were satisfactory. No *B. subtilis* or other microorganisms were recovered with the cotton swabs. However, the surface sample from the windowsill that was inoculated into a thioglycolate broth tube showed turbidity. The thioglycolate broth tube inoculated with *B. subtilis* as a control also showed a comparative amount of turbidity. Microscopic examination with Gram stain of both the control and test sample showed the presence of gram-positive rods. Subsequent bacteriological examination and testing established that the recovered microorganism from the ceramic windowsill was *Bacillus cereus*. One of the possible sources for *B. cereus* contamination following disinfection is contamination of the broth tube or cotton swab, or entrance of the organism into the operating room through the ventilation system.

A ventilation smoke tube was used to determine if air leaked around the door seams. It also was used to determine the direction of air currents from the exhaust duct after aeration of the operating room commenced. Air leakage and current tests were run before, during, and following dissemination of the BPL vapor to preclude difficulties with penetration of the vapors into other occupied areas within the hospital.

An unforeseen emergency surgical operation was begun in the operating room adjacent to the service room that also served the operating room being disinfected, at the same time that the supply fan was turned on (Fig. 1). Because of the wind direction and atmospheric conditions, vapors of BPL did not enter the ventilation supply system to the operating suite, so that the emergency operation proceeded without incident.

Subsequently, all surfaces within the disinfected operating room and its equipment were wiped down with cloths moistened with

a detergent-disinfectant solution.

DISINFECTING PATIENT WARD

In preparing the patient ward for disinfection, the relative humidity was raised to 77 per cent by spraying tepid water from a generator. The ambient temperature was raised to 74° F.

Before the BPL vapor was disseminated, 14 carefully delimited surfaces within the ward were seeded with spores of *B. subtilis* var. *niger* in the same manner as in the operating room. Areas seeded were doorknob, beds, chair, stool, floor and wall surfaces, bed stand, curtain rod, wastebasket, windowsill, and footstool.

The oscillating fan opposite the generator location (see Fig. 1) was turned on at low speed to help distribute the BPL vapors throughout the ward with some degree of homogeneity.

As in the procedure followed in the operating room, the room was sealed to prevent the escape of the BPL vapor during the disinfection process. Cracks on the windows were taped with pressure-sensitive tape. A window with double doors beneath, which serves as a doorway to the porch outside this ward, was arranged so that later both it and the doors could be opened from the outside. Windows to patients' rooms along the second floor corridor were closed to preclude entrance of BPL vapors into the rooms during the phases of BPL disinfection. All doors and drawers of the metal bed stands were opened. The generator used for disseminating the BPL vapor was positioned so that BPL vapors would not impinge directly on any surface. In addition, absorbent paper was placed beneath and approximately 8 ft. in front of the generator. From personal experience we have learned that asphalt tile is dissolved if liquid droplets of undiluted BPL fall directly on the tile. After the generator was turned on by one person, who then immediately left the ward, the peripheral cracks of the door were taped with pressure-sensitive tape.

Smoke tubes were used to determine if any air was leaking from within the ward into the corridor during dissemination of the BPL, during the contact period, or during aeration.

A two-hour contact period was maintained after disseminating the BPL. Then the double doors beneath the one window were opened from the outside and a 20-in. exhaust fan was placed in the opening. The BPL vapors were exhausted from the room with the fan positioned so that the air stream directed the BPL-laden air away from patients' rooms. During the initial aeration period, personnel monitored the patients' rooms for penetration of BPL vapors.

After two hours' aeration, personnel could enter the ward without chemical respiratory protective masks. The level of BPL vapors at that time was below the detectable range of the civil defense detection tubes. However, to insure that all residual BPL vapors and breakdown products were removed from the ward, the other oscillating wall-mounted fan and the window air-conditioner fan were turned on and allowed to run overnight, in addition to the window exhaust fan. The tape was removed from the door after the two-hour aeration period to permit a greater volume of air to be drawn from the hallway through the openings around the door. With the above arrangement of fans the ward was under slight negative pressure during the entire aeration period. This prevented vapors of BPL from entering adjoining areas.

After the initial two-hour aeration, sterile cotton swabs moistened with physiological saline were used to sample the previously seeded areas for the recovery of *B. subtilis*. Upon return to the microbiological laboratory, the cotton swabs were aseptically streaked on corn steep agar (see Appendix) in plastic petri dishes. The plates were incubated at 37° C. for 48 hours. No *B. subtilis* or other microorganisms were recovered by this surface plating technique after disinfection of the ward with BPL. This showed that a satisfactory disinfection was achieved. Subsequently, the ward and its contents were wiped with water-moistened cloths.

SUMMARY AND DISCUSSION

A hospital ward and an operating room were disinfected by disseminating beta-propiolactone

(BPL) in a concentration of one gal. of BPL for each 12,000 to 16,000 cu. ft. of space. The temperature was elevated to 74° F. and the relative humidity to 75 per cent, the supply and exhaust ventilation systems were turned off, and all seams and openings were blocked before BPL was disseminated. It was possible to enter the disinfected areas after two hours of forced aeration. However, overnight aeration is advisable whenever BPL is used.

The efficacy of BPL disinfection was determined by seeding areas with spores of *Bacillus subtilis* var. *niger*, (count: 1×10^4 spores per ml.) No *B. subtilis* was recovered from these areas following disinfection.

Critical visual examination of the operating room showed no apparent damage to items occasionally affected by liquid BPL, such as the painted surfaces, synthetic neoprene products, or plastic items. In the ward the only apparent damage was to the varnished door. It is the opinion of the writer, after examining other doors of the same age (approximately 25 years) throughout the hospital, that any

elevation of humidity would have caused the slight blistering of the varnish that was evident on the door to the ward disinfected with BPL.

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APPENDIX

The author has furnished the following information about (1) supplies, (2) equipment, and (3) the corn steep liquor medium used in the bacteriological tests following disinfection.

The detergent-disinfectant used was Tergisyl,® manufactured by Lehn & Fink Products Corp., Toledo, Ohio 43612. Active ingredients: orthohydroxydiphenyl, paratertiary amylphenol, sodium sulfonates.

The generator used for dissemination of the BPL vapor was a Challenger generator,® Model 5100 CF.

The sterile cotton swabs used for broth inoculation tests following disinfection of the operating room were manufactured by Falcon Plastics, Division of B-D Laboratories, Inc., 3500 W. 83rd St., Los Angeles 90045.

The ventilation smoke tube used to detect air leakage and direction of air currents was manufactured by Mine Safety Appliances Co., Pittsburgh, 15208.

The corn steep liquor medium was prepared as follows:

To make the stock solution, 500 gms. crude blackstrap molasses were dissolved in 1250 ml. corn steep liquor.

The components per liter in the medium are the following: 31 ml. molasses and corn steep stock solution; 20 gms. bacto-agar; 1000 ml. distilled water; 0.75 ml. 5 N sodium hydroxide; and 10 mg. actidione (dry).

To prepare the medium, dissolve bacto-agar in water completely. Add molasses and corn steep stock solution and actidione. Adjust pH, then autoclave. (Final pH to be 6.8-7.2.)